4. **Mixing granular materials** (grade 5). This activity transitions students from direct observations of mass and volume to a very abstract idea that matter is composed of particles much too small to be seen. The learning outcome is that everyday observations can be used to show that such particles can be inferred. However, in doing this activity, it is best to not set the students thinking about atoms and such until after the activity is complete. Let them state that matter is composed of particles, and most of them will be able to develop that perspective themselves.

The set-up in this activity is simple, but I recommend you do this as a demonstration rather than have them do it – it's a little messy and involves a somewhat toxic chemical, ethanol (drinking alcohol, but still dangerous around children).

You will need about 1 cup each of some rice, sand, glass marbles, water, and 95-100% alcohol (from your local hardware store in the paint section), a plastic 100 mL graduated cylinder and the same OHaus balance you used in the previous activity. You will also need a 6 ounce plastic cup for mixing things in. A funnel helps, but I just use a sheet of paper twisted into the shape of a funnel, for transferring the sand or rice to the graduated cylinder.

Each student should have a notebook to keep track of the data. The activity should begin by asking students about their recollection of the conservation of mass: is mass always conserved? Then ask them to transfer this to volume – do they think volume is conserved or not?

Set the graduated cylinder on the scale and set it to read zero. Transfer as precisely as possible 50 mL of rice to the cylinder and determine its mass (have students record this) then pour the rice into the plastic cup. Repeat with a second 50 mL of rice – weigh and record this – then transfer to the first batch of rice. Pour all the rice into the cylinder. Have students predict the resulting mass (have them add the two measurements together), and see if the actual summed mass is the same. Now check to see what the sum of the volumes is on the graduated cylinder – it should be right at 100 mL. In other words, both mass and volume are conserved in this case.

Repeat this with sand – measure volume and mass of 50 mL of sand twice, mix them and determine volume and mass of the total to see if both are conserved.

This time, mix it up, by recording the mass of 50 mL of the marbles (or at least as close as possible), then combining with 50 mL of sand. Measure the mixture – is the mass still conserved (yes) and is the volume still conserved (no). Pass the graduated cylinder around and have the students verify that the volume is significantly less than 100 mL. Ask what happened to the volume. Most students will say that the particles of sand went into spaces between the marbles.

Do this again with the rice and sand, instead of the marbles. Again students will see that the mass is conserved while volume is not. Ask again for an explanation and they will likely state that the smaller sand particles went in between the larger rice grains.

Finally repeat using the sand and water (note – never try this by mixing rice with water – you get a mess!). Again, students will see that mass is conserved, as it always is, but that volume is not, and they will probably be able to articulate that the water went in between the gains of sand.

At this point, you might try to repeat this with 50 mL of water plus 50 mL of water – since the same material in both cases are mixed, they will see that both mass and volume are conserved. While this step is optional, if you do it, you might stop here and ask students to make a rule about mixing materials. Their rule might read like this: If you mix the same thing, both volume and mass are conserved, but if you mix different things, the mass is conserved, but the volume is not. They should also explain this is so because smaller particles can fit between larger particles.

Now follows the essential demonstration: Measure 50 mL water and its mass, then 50 mL alcohol and its mass, mix in the plastic cup, then pour back into the graduated cylinder. Be very careful with this to be sure nothing is lost! Check the total mass – is it conserved? (Yes) – what about the volume? (it is lower!

Probably down to about 94-95 mL. How can we account for this? Students may say something about evaporation, but note – the mass is conserved, so everything is present! I like to go around the room and have everyone commit to the same idea – the volume is less because smaller particles went in between larger particles – "But can you see the particles?" No, is the answer – they are much too small, but the parallel with the model of sand, rice, and marbles suggests pretty strongly that the water and alcohol are indeed made of particles. We cannot say with this experiment, which has the bigger particles, but only, that they have particles of different size.

This should be followed up with a discussion of models and how they can be used in science. Note that developing and using models is one of the key science practices in NGSS. Sand, rice, and marbles are models indicating how particles behave. All models are limited in their usefulness, and in this activity, the limit is that the particles can actually be seen, while the particles in ordinary matter are much too small. But without understanding the model, it is not clear how to interpret the observation that mixing water and alcohol results in a lower volume.

In closing: At the middle school level, additional experiments would be done to reinforce the ideas arising from each of the activities described above, and to add to our understanding that atomic rearrangements are behind chemical changes.

Note that concrete ideas arise from concrete experiences, but also that as children grow in sophistication, their concrete experiences can also move their thinking into the realm of the invisible. We cannot see the particles of which nature is composed, but their existence arises from observations we can easily make, and once their existence is revealed many other everyday experiences can be explained. Children at the fifth grade level can be stimulated further by asking them to use the particulate nature of matter to explain each of the following:

- How can things move through a liquid such as water?
- How can odors move through air to our noses so we can smell them?
- How might we account for how much heavier a rock is compared with a piece of wood of similar size?
- How might particles in a liquid behave differently from particles in solids?
- What happens to particles when solids such as sugar or salt dissolve in water?